The PolicyTracker Spectrum Handbook 2020

Updated to reflect WRC-19 decisions

Sample pages:
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PolicyTracker

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Executive summary

This report is the complete guide to commercial spectrum policy and usage in the mobile and satellite industries, as well as in the OTT sector.

It profiles the main bands and outlines the strategies of major equipment and software vendors, as well mobile and satellite operators. It also gives an overview of policy developments in the biggest economies.

We have comprehensively updated the report in light of the outcomes of the ITU's latest World Radiocommunication Conference, WRC-19.

WRC-19 resulted in an extra 17.25 GHz of spectrum above 24 GHz for mobile networks

Context

WRC-19

ITU's World Radiocommunication Conferences have the biggest influence on future spectrum usage, and the most recent one, WRC-19, concluded in November 2019. The previous conference, WRC-15, set the agenda to identify frequencies above 24 GHz for IMT (International Mobile Telecommunications).

Significantly, the 28 GHz band was off the agenda for WRC-19, due to concerns raised by the incumbent satellite users. Nonetheless, this band has become the most commonly used mmWave frequency for early 5G[1] deployments.

WRC-19 resulted in a significant amount of millimetre (mmWave) spectrum being harmonised for IMT use, including global identifications for 26 GHz and 40 GHz, as well as 70 GHz on a shared use basis with wireless access systems such as WiGig. In addition, 45.5–47 GHz and 47.2–48.2 GHz found significant support, while falling short of a global IMT identification.

In total, WRC-19 found 17.25 GHz of spectrum above 24 GHz for IMT across these bands, which in the coming years will be vital for 5G network development.

WRC-23

WRC-23 will shift the focus onto harmonising more mid-band spectrum for IMT. In particular, it will consider further harmonisation within the satellite C-band, namely:

WRC-23 will focus on harmonizing further mid-band frequencies

- IMT identification in 3300–3400 MHz, amending footnotes for Regions 1 and 2
- IMT identification in 3600–3800 MHz in Region 2
- Primary mobile allocation for 3600–3800 MHz in Region 1.

Allowing cellular into the predominantly satellite C-band generated tense debate at the 2007 and 2015 conferences and that is likely to happen again in 2023.

[1] *The ITU terminology for 5G is in fact "IMT 2020" but for simplicity we refer to this throughout as 5G.*

1. Introduction

Aims

The PolicyTracker Spectrum Handbook explains how the airwaves are currently used for mobile services and how they are likely to be used in the future. It does this through several perspectives:

- By examining current mobile bands, i.e. those used for 2G,3G, 4G or 5G, although for the latter few countries are actually offering commercial services (Chapter 2)
- By looking at other possible 5G bands (Chapter 3)
- By examining the views of the leading players in the spectrum market (Chapters 4, 5, 6 and 7)
- By considering the approaches adopted in the leading economies (Chapter 8).

We identify trends, in terms of both spectrum usage and sentiment and emerging policy directions

We identify trends, not just in terms of spectrum usage but also sentiment and emerging policy directions. Our particular focus is developments in the past year, but earlier events are often more important, so are also explained.

Current usage and trends are illustrated by graphs, diagrams and charts taken from PolicyTracker's Spectrum Database[2].

This edition of the PolicyTracker Spectrum Handbook has been comprehensively updated to reflect the key decisions arising from WRC-19.

Structure

Chapter 2 sets out which bands are currently used for mobile services, incorporating those bands which have been assigned for 5G in some countries but not have not yet come into wide global usage. The focus here is to show in which ITU regions the bands are used and for which technologies.

We discuss the most-used mobile bands, considering their current usage and how that is likely to change in the coming years. The report also includes some bands which are not currently very popular, but may become more important in the coming years, such as the L-band.

Chapter 3 examines those bands where 5G usage has been through the ITU or though other standardisation processes, but services have not yet been deployed in any country. The focus here is to identify which bands are most likely to be used and in what timescale by examining the level of support among vendors, operators and administrations.

Chapter 4 examines the views of the leading telecoms equipment vendors on spectrum for 4G and 5G, Chapter 5 does the same for the biggest global operators. Chapters 6 and 7 examine the spectrum policy positions of OTT players and the satellite industry. With all these chapters, we explain the issues on which the companies are campaigning and consider where their priorities lie.

[2] *A database of allocations and assignments in over 100 countries, which also gives information on pricing*

900 MHz

GSM-based 2G services use 900 MHz across Europe, Africa, and Asia. The band is set to be refarmed for 4G and 5G services over the long-term.

Uplink starts	880
Uplink ends	915
Downlink starts	925
Downlink ends	960
E-UTRA band number	8

The band will be supported by 5G NR

The enormously successful GSM 2G standard initially used this band. The standard had its roots in Europe but over time the band was assigned for 2G across Africa, Asia, and South America too. The band is also used for 4G services in some places, and is available for 5G too.

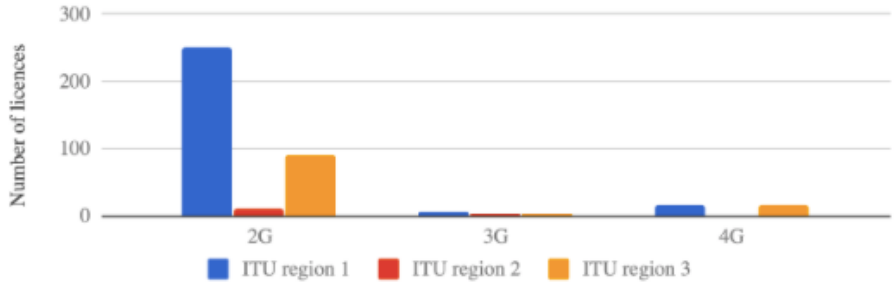
The band has been assigned for mobile usage in around 50 countries in Regions 1 and 3. It also used in two French territories in the Caribbean, as well as Venezuela.

The first 900 MHz band licences were issued in the late 1980s and early 1990s with GSM (2G) services in mind. Many licences will expire over the next 15 years. The majority of regulators are choosing to auction the rights to these frequencies alongside other bands as the current licence expire. These auctions continue to be relatively expensive in general. For example, a hybrid assignment in Hong Kong for 900 MHz band licences beginning in 2021 cost the equivalent of $0.90/MHz/POP. By contrast, Denmark re-auctioned the band in Q2 2019 but waived all fees on the licences in return for commitments to improve coverage.

The UK does not require operators to regularly re-obtain spectrum they have already brought, but has instead decided to charge spectrum fees that reflect the value of the band. The regulators calculations for these fees were subject to extensive litigation that ended in December 2018 with a decision to charge each operator £1.09 million per MHz per year for the band, the rough equivalent of $0.02/MHz/POP every year.

Four regulators in Europe, and three in Asia, currently have plans to award the band, mostly where licences are expiring or there are residual available frequencies.

18) 900 MHz: Regional usage by technology



In a small number of cases, the band is used for 3G services, and since late 2013, 4G (LTE). The band will be supported by 5G NR and Europe's harmonising decisions have already been amended to allow 5G Active Antenna Systems in the band. 3GPP has also agreed a new supplemental uplink band (n81) at 880 – 915 MHz, which overlaps with this band.

Its relatively good propagation qualities means it could be a good candidate for some GSM- or LTE-based Machine to Machine communications.

The GSA, representing mobile equipment suppliers, notes the band's importance for 4G but reports that operators are focussing on other 4G bands such as 1800 MHz, 800 MHz, 2.1 GHz, and 2.6 GHz band. It appears that the other traditional "GSM band" (1800 MHz) is more attractive for operators wishing to roll out 4G services. The reported popularity of the 2.1 GHz band for LTE suggests that refarming of spectrum from 3G to 4G may be happening faster than refarming from 2G to 4G.

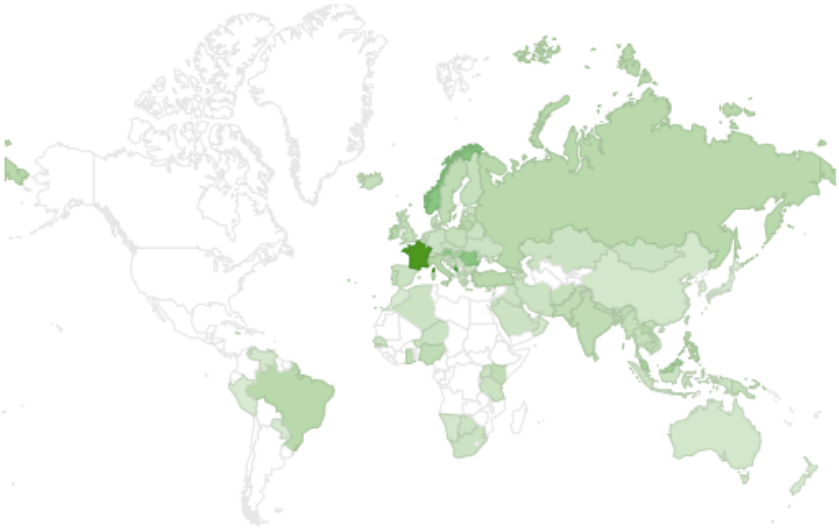
Australia is also attempting to reconfigure its band plan to maximise the use of 900 MHz for mobile broadband

The band overlaps with frequencies used for narrowband communications in the USA. The US regulator, the FCC, is currently proposing amending these rules so that licensees can use 4G (band [n]8) technologies in the band, ostensibly for smart grids.

Australia is also attempting to reconfigure its band plan to maximise the use of 900 MHz for mobile broadband.

The band will be discussed at WRC-23 in the context of the review of the 470 – 960 MHz band in Region 1, and an agenda item on the use of high-altitude platform stations as IMT base stations.

19) Map: 900 MHz in the major economies



Darker green indicates a higher number of licences

10-10.5 GHz

WRC-23 will consider an IMT identification for 10-10.5 GHz in Region 2. Prior to WRC-19 there appeared limited international pressure for commercial use of this spectrum. Momentum will build around 10 GHz as a licensed 5G candidate band as a result of WRC-19.

Band overview

There are no mature plans for spectrum assignments, but international momentum may drive regulators to revisit the band for future 5G services.

Uplink starts	10000
Uplink ends	10500
E-UTRA band number	n/a

The frequency range does not have a mobile service allocation in Region 2, unlike Regions 1 and 3. Nonetheless, a number of nations around the world, including nations in the Americas, have signed onto a primary mobile allocation for this spectrum via Radio Regulation footnotes, meaning that IMT can be implemented without an ITU IMT identification.

In Regions 1 and 3, 10-10.4 GHz is allocated on a co-primary basis to mobile services (along with Earth Exploration Satellite Services (EESS), fixed, mobile, radiolocation and amateur services, with the latter service allocated on a secondary basis. 10.4-10.45 GHz is allocated on a primary basis to radiolocation, fixed, mobile and on a secondary basis to amateur services.

In Region 2, 10-10.4 GHz is allocated to EESS and radiolocation on a primary basis and to amateur services on a secondary basis. 10.4-10.5 GHz is allocated to radiolocation (primary) and amateur (secondary). There is no fixed or mobile allocation in Region 2, although 12 Latin American nations have added a primary mobile allocation at 10-10.45 GHz through additions to Radio Regulation footnotes. Twenty-five nations across Africa, the Asia-Pacific, Latin America and Europe have also added a primary mobile allocation for 10.4-10.5 GHz including China, Brazil, Japan and Germany. There is an overlap with 7 countries adopting a mobile allocation across 10-10.5 GHz.

There is also some military use of the 10-10.5 GHz range in certain jurisdictions including European nations and the US. In addition, the band 9.975-10.025 MHz is allocated to the meteorological-satellite service on a secondary basis for use by weather radars across all three Regions.

The 10-10.5 GHz band has been elevated as a 5G candidate band with WRC-19 directing WRC-23 to consider an IMT identification for this frequency range in Region 2.

Consideration of mobile use of 10 GHz in the US

In the US the 10-10.5 GHz range is allocated on a primary basis to federal radiolocation and on a secondary basis to non-government radiolocation and amateur services. 10.45-10.5 GHz is also allocated to amateur satellite services on a secondary basis. Since 2014, the FCC has an open rulemaking (RM-11715) to consider possible fixed and mobile sharing of the 10-10.5 GHz range. Supporters of mobile use of this band include Mimosa Networks, Qualcomm, the Open Technology Institute, WISPA, Public Knowledge, the New America Foundation, the DSA and six members of Congress. In that the

US agreed to support the CITEL Region 2 position on mid-band spectrum IMT studies.

Outlook – momentum will build around licensed use of 10 GHz spectrum

There is a large swath of 500 MHz of spectrum in this frequency range with spectral characteristics suited to 5G service provision. For example, according to some vendors and wireless service providers, 10-10.5 GHz is ripe spectrum for small cell deployments and is less susceptible to attenuation due to rain-fading effects than higher mmWave bands. According to Qualcomm, "Deploying small cell technology at 10 GHz may be a perfect means of enabling mobile broadband connectivity in this band given that these higher frequency signals have higher propagation losses than the sub-3 GHz bands that traditionally have been used for mobile broadband connectivity via macrocells".

A number of think tank-like organisations also earmark 10 GHz as a strong candidate for spectrum sharing, while 3GPP considers that spectrum between 7 to 27 GHz is suited to eMBB and URLCC, the latter requiring case-by-case analysis.

"Deploying small cell technology at 10 GHz may be a perfect means of enabling mobile broadband connectivity in this band"

These factors will make 10-10.5 GHz a focus band for the mobile industry over the next four years in the lead up to WRC-23. In addition, nations in Regions 1 and 3 that have a primary mobile allocation for 10-10.4 GHz or 10.4-10.5 GHz and those in Region 2 that have signed onto mobile service footnotes, can implement IMT in the band without an ITU IMT identification. If this occurs it will support 5G ecosystem development for 10 GHz.

There is likely to be significant support for WRC-23 IMT identification for 10 GHz spectrum based on the historical record associated with this band. A range of stakeholders supported WRC-15 consideration of a possible IMT identification for 10 GHz spectrum – with different frequency ranges proposed for sharing studies. These stakeholders include regional organisations (ATU, CITEL), nations including South Korea, Japan, Singapore, Australia and China along with SADC, ECCAS and ECAO countries, and vendors including Qualcomm, Ericsson, Samsung and Mitsubishi Electric.

In addition to these 10 GHz IMT advocates, among supporters of a WRC-19 mandate to ITU-R to study 10-10.5 GHz, or portions thereof, for IMT are the FCC, as noted, OFCOM in the UK and Japan's Mobile Communications Promotion Forum (5GMF). That said, there is already strong opposition to this WRC-23 Agenda Item from amateur users.

Nokia

Nokia supports a wide range of low, mid (particularly 3.5 GHz) and high-band spectrum for 5G and is advocating for the release of a swath of mmWave bands in the widest possible contiguous frequency ranges. After 26 GHz and 28 GHz, Nokia regards 37-43.5 GHz as the next promising band range for 5G.

Nokia is a global provider of telecommunications equipment, software and services and is at the forefront in the development of new 5G technologies. Nokia lays claim to 1,516 5G declared family 5G patents.

Nokia's views on WRC-19 mmWave bands

Nokia recognises the growing ecosystem supporting 5G in the 28 GHz band that will also benefit the development of the 26 GHz ecosystem. Where the lower portion of the 26 GHz band is heavily used, Nokia suggests that regulators should, at least, release the upper 1 GHz portion of the band (26.5 – 27.5 GHz). Nokia believes that reasonable 26 GHz out-of-band 26 GHz emission limits to protect EESS operating in 23.6-24.0 GHz spectrum are -32 dBW/200 MHz for base stations and -28 dBW/200 MHz for terminals. WRC-19 has identified 24.25-27.5 GHz for IMT use, setting emission limits that are on par with those recommended by Nokia. Nokia does not support limits on the aggregate power levels produced by 26 GHz terrestrial systems. WRC-19 concurs with this position and sets no in-band 26 GHz limits.

Nokia sees excellent opportunities for the global harmonization of the 37 – 43.5 GHz range and considers that it could provide a common base for an ecosystem, potentially resulting in more than one 3GPP identified band to cater for regional differences in available frequencies within this range and will welcome WRC-19's IMT identification of the 37 – 43.5 GHz range for IMT globally. Nokia supports the release of 45.5 – 47 GHz and 47.2 – 50.2 GHz spectrum for 5G use. WRC-19 also added an IMT identification for 45.5 – 47 GHz and 47.2 – 48.2 GHz in scores of nations across all three ITU regions. The vendor considers that spectrum supporting 5G will include 66 – 71 GHz and sees this range, which is close to license-exempt WiGig frequencies, as a priority for industry. Nokia supports an IMT identification for 66 – 71 GHz, as deemed by WRC-19 globally.

Using lower frequency bands for 5G

Nokia supports IMT use of the 2300 MHz band and also sees the potential for use of 2600 MHz spectrum for 5G. WRC-19 encourages national administrations to consider greater use of both the 2.3 and 2.6 GHz bands for IMT. Nokia also supports 5G use of 4800-4900 MHz spectrum, noting that 3GPP has developed technical specification for 5G New Radio covering the 4.4-5.0 GHz range, and scores of nations around the world signed onto IMT footnotes for the 4.9 GHz band at WRC-19.

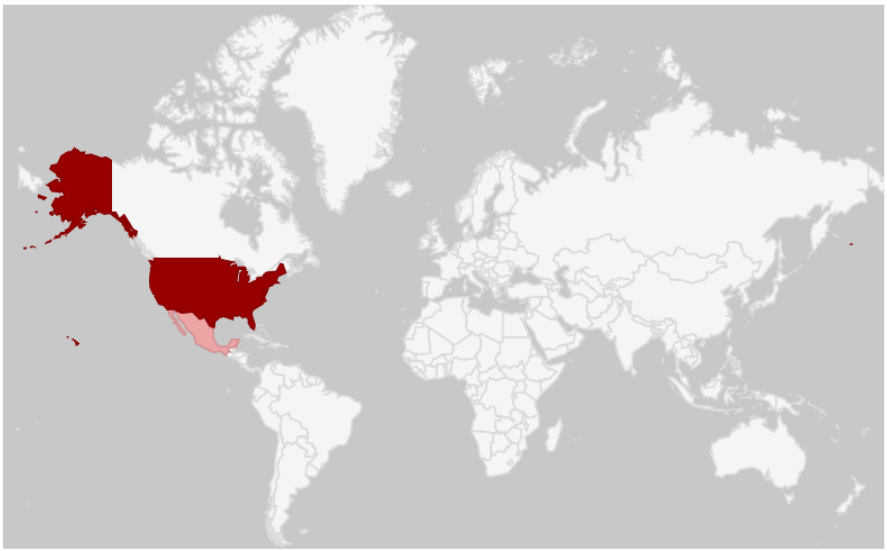
AT&T

US and Mexican operator AT&T says it's the first US company to introduce mobile 5G service in parts of several cities. That deployment is scheduled to exland nationwide by 2020 as the company continues to invest heavily in 5G. Current spectrum priorities include the sub- I GHz bands, as well as the 2.5, 3.5, 3.7-4.2, 6, 37, 39 and 47 GHz bands.

These 5G services use millimetre wave spectrum, with peak speeds of over 2 gigabits per second

AT&T's 4G LTE networks covered, as of December 2018, over 400 million people in North America, its February 2019 US Securities and Exchange Commission 10K annual report said. In addition to communications services, it offers broadband, video entertainment and wireless services, as well as content through Warner Media. AT&T Latin America provides mobile services in Mexico, along with pay-TV service in 11 countries in South America and the Caribbean. During 2018, it mostly completed build-out of a 4G LTE network in Mexico covering around 100 million people and businesses.

35) AT&T's global spectrum licences



The darkest red shows the largest spectrum holdings. More details on methodology

The operator is considering redeploying its 3G spectrum, with 3G services projected to terminate in early 2022.

AT&T is in the process of rolling out 5G technology in multiple US cities. It introduced service in parts of 12 cities and plans to expand nationwide by early 2020.

These 5G services use millimetre wave spectrum, with peak speeds of over 2 gigabits per second, but AT&T made its first data transfer over sub-6 GHz spectrum in July 2019, it said. "We believe deploying 5G in both mmWave and sub-6 bands will provide the best mix of speeds, latency and coverage areas that are needed to fuel" exciting 5G experiences. The operator is also a key contributor to development of 5G standards through the 3rd Generation Partnership Project.

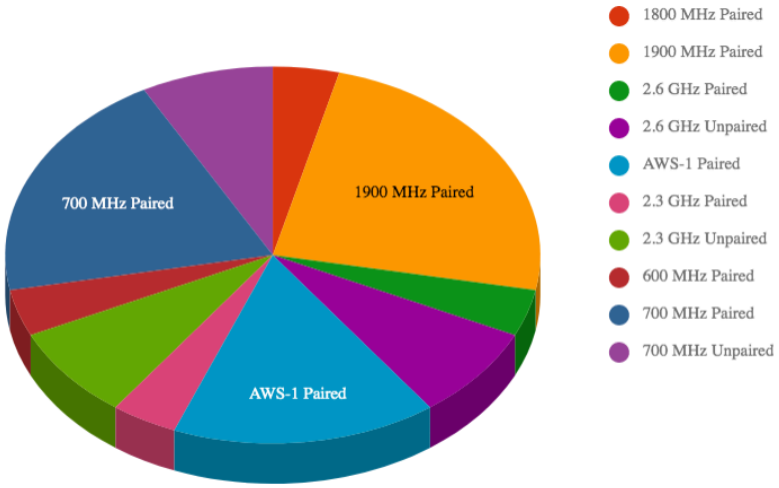
4G spectrum position

In April 2019, the company launched a narrow-band Internet of Things network, after updating the software at its 4G LTE cell sites across the country. The move aims to "unlock the next wave of IoT connections" and it is a "big step toward massive IoT and 5G." With NB-IoT, AT&T offers two complementary low-power wide area networks in the US and Mexico, including an LTE-M network launched in 2017. Both are designed for the IoT within licensed spectrum and provide carrier-grade security. Devices that ride on them can be configured to go dormant when not in use, opening a range of uses that don't need constant mobile connections, such as leak detectors or smart appliances.

A collaboration between AT&T, KDDI and Toyota will enable 4G LTE connectivity for some new cars

A collaboration between AT&T, KDDI and Toyota Motor North America will enable 4G LTE connectivity for some new model Toyota and Lexus cars and trucks starting in the fall of 2019 with 2020 model year vehicles, the companies announced. Features will include Wi-Fi hotspots so owners of the cars can stream, browse and share entertainment among multiple smartphones from the open road, and connected services such as remote car-starts and diagnostics.

36) Which bands sub-3 GHz bands AT&T use?



Based on the number of licenses held in each band. More details on methodology.

5G spectrum position

The operator set out its current thinking on spectrum policy issues in two January 2019 statements. One discusses the need for a range of spectrum bands for commercial mobile broadband services. The other focuses on the 2.5 GHz educational broadcast service band, 3.5 GHz citizens band radio services band, C-band (4.0-8.0 GHz). 3.7-4.2 GHz band and 6 GHz band.

AT&T's average spectrum depth in mmWave increased by two-thirds to more than 630 MHz nationwide

AT&T won 24 GHz spectrum licences covering more than 98% of the US population at auction, it said in June 2019. All the licences were in the upper part of the band, giving the operator stronger nationwide coverage and greater spectrum depth and capacity in many top markets where demand is often highest. The spectrum will boost AT&T's 5G strategy, it said. Added to the mmWave spectrum it already holds in 39 GHz, "AT&T's average

spectrum depth in mmWave increased by two-thirds to more than 630 MHz nationwide." The spectrum cost around $980 million.

The US Federal Communications Commission plans to auction "Spectrum Frontier" spectrum in the upper 37, 39 and 47 GHz bands starting in December 2019. That spectrum is "critical for successfully rolling out 5G to American consumers, blogged AT&T Executive Vice President Regulatory & State External Affairs Joan Marsh

Facebook

Facebook is interested in a broad range of spectrum resource for a wide variety of use cases. WRC-19 allocated additional mmWave spectrum for High Altitude Platform stations (HAPS), a decision championed by Facebook. Facebook does not support WRC-19's IMT identification for 66-71 GHz or WRC-23's consideration of IMT identification for 6 GHz spectrum.

Facebook's views on WRC-19 mmWave bands

Ahead of WRC-19, Facebook continued to champion the development of HAPS, saying it wanted to achieve greater global connectivity by loosening some of the rules for using various fixed service bands to connect to stationary drones hovering 20-50 km above the Earth. In the US, Facebook supports spectrum for HAPS in the 21.5-22 GHz, 24.25-27.5 GHz. 28/31 GHz, 38-39.5 GHz and 47 GHz ranges. Facebook is also examining HAPS operations in the US across a range of spectrum bands including 25.5-27.5 GHz, 1715-1850 MHz, 2200-2290 MHz and 2360-2483 MHz. It has also received permission to test HAPS at 37.75-39.75 GHz.

WRC-19 identified additional high-band spectrum for HAPS with 31-31.3 GHz and 38-39.5 GHz allocated globally. In Region 2, additional spectrum for HAPS use is allocated in the 21.4-22 GHz, 24.25-25.25 GHz and 25.25-27.5 GHz ranges. Facebook supports a global HAPS service identification for 27.9-28.2 GHz. WRC-19 did not adopt a harmonization decision on this range where the only change was the addition of China to a Radio Regulation footnote allowing use of this spectrum for HAPS and bringing the number of signatories to this footnote to twenty-four across nations in Regions 1 and 3.

WRC-19 has identified the 24.25-27.5 range for IMT use globally along with 37-43.5 GHz. While accepting that this spectrum has been earmarked for 5G services, Facebook will continue to support flexible use of these mmWave ranges spectrum across different platforms, including HAPS. In Facebook's view, 5G is a network of networks – mobile, HAPS, satellite, Wi-Fi etc. where dynamic spectrum sharing is a critical enabler.

Facebook's urban FWA Terragraph solution uses unlicensed 60 GHz spectrum and the FCC has also granted Facebook permission to use 71-76/81-86 GHz spectrum on an experimental basis for small satellite-based Internet service provision. Another WRC-19 priority for Facebook was no change under AI 1.13 to the 66-71 GHz band, which Facebook said "is poised to extend the innovation, development, and deployment of 5G services already occurring in the adjacent 57-66 GHz band." Imposing an IMT identification in the 66-71 GHz band could "lead to regulatory uncertainty, freeze commercial investment, and hinder international harmonization, as a number of administrations have already made or planned to make the band unlicensed." Contrary to Facebook's position, WRC-19 adopted a global IMT identification for 66-71 GHz.

…an IMT identification in the 66-71 GHz band could lead to regulatory uncertainty

Facebook's views on non WRC-19 mmWave bands

WRC-19 directs WRC-23 to consider HAPS as high-altitude IMT base stations (HIBS) using mobile bands below 2.7 GHz, across 700 – 900 MHz,

India

The Modi government is intent on modernising spectrum policy but its attempts to reduce reserve prices in the upcoming mega-auction are meeting heavy resistance.

The most important spectrum policy document in India over the next 12 months will be the auction conditions for the forthcoming mega auction of 4G and 5G radio spectrum. Up for grabs are frequencies in the 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.3 GHz, 2.6 GHz and 3.3-3.6 GHz bands, worth billions of dollars. It will be the country's first auction since October 2016.

The sell-off is significant in deciding which companies will add to their spectrum stockpiles (a newcomer is technically possible but viewed as unlikely) as the county prepares for the transition from 4G to 5G. It is also an important moment in revealing what is the country's prevalent thinking when it comes to spectrum allocation.

Historically, India has generally set high reserve prices and offered a relatively meagre amount of spectrum so driving up auction returns, with an eye on boosting the state's finances. This policy, which been decried by the mobile industry, has been blamed for some of the industry's recent financial distress, although the assault of Reliance Jio Infocomm and its innovative straight-to-4G service launched in 2016 has obviously had a major role too. The industry now has just three privately-owned players: Vodafone Idea, Reliance Jio and Bharti Airtel.

Yet, the government of Narendra Modi has seemed intent on breaking away from the traditional policy. The Department of Telecommunications requested regulator Trai review its proposed reserve prices for the mega auction. The regulator refused. On the opposing side, Vodafone Idea and Bharti Airtel have warned the reserve prices are not affordable. The process is at an impasse. The government had scheduled the auction to take place before the end of 2019. That now looks optimistic.

The government could overrule the regulator's decision but might be reluctant because decisions with such a major financial impact on private companies are scrutinised in India by the Comptroller and Auditor General and questions asked. Compared to previous administrations, Modi's has a relatively clean reputation and would not want it to be questioned. Trai, on the other hand, does not want to set a precedent by backing down. The way forward is unclear.

Five year plan

The philosophical position of the Modi government on spectrum pricing was summed up in the National Digital Communications Policy, published in 2018. The five-year outlook, in its own words, "attempts to outline a set of goals, initiatives, strategies and intended policy outcomes" to be achieved by 2022.

This is a statement of intent by the Modi government to moderate traditional practice

To accomplish these goals, the government proposed three missions, one of which is termed Connect India. It has a number of strategies. One of which covers spectrum. Its stated aim is to "Recognise Spectrum as a key natural

9. Methodology for diagrams

An explanation of how some of the graphics in this report are generated from the PolicyTracker Spectrum Database (PSD) the world's most comprehensive listing of assignments, pricing and allocations.

About the PolicyTracker Spectrum Database

The graphics in the 4G section are derived from raw data in the PSD. Please note:

- This covers over 120 of the biggest economies, but not the whole world
- It only covers bands commonly used for mobile or wireless broadband services

The charts below are based on the issuing of licences:

- if an operator holds two separate licences issued at different times, this will be counted as two licences
    - ...even though they may be both in the same band and used congruently

General points about the graphs

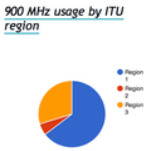
The scale may vary: when comparing one graph against another please note that the scales may differ. For example very few countries have allocated 2.3 GHz to mobile, so the scale on the graph representing this has a maximum value of 3 whereas in a popular band like 2.1 GHz the scale goes to 25.

Specific points about individual diagrams

Bar chart: regional usage by technology

- Shows the number of licences used for 2G,3G and 4G in the ITU regions
- As above only includes licences in the PSD, licences from smaller countries are not included
- However, it gives an accurate impression based on a large sample

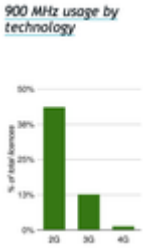
Pie chart: usage by ITU region



- Shows the total number of licences in this band in the PSD in XXX MHz
- Counts the number in the three ITU regions
- The pie chart shows these number as percentages
- There may be more XXX MHz licences around the world in countries not covered by the PSD

- However, this chart gives an accurate representation of the relative proportions

Bar chart: usage by technology

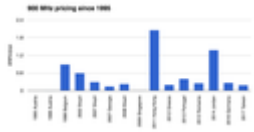


- Counts the number of licences in this band used for 2G, 3G and 4G divides that figure by the total number of 2G, 3G and 4G
- Gives that proportion as a percentage
- As above, most countries are covered but not all

Map: use of a band in the major economies

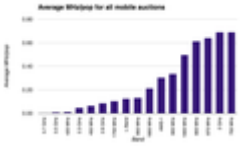
- Shows the countries where this band is licensed
- Darker green indicates a greater number of licences
- As above, most countries are covered but not all

Bar chart: pricing for a band since a particular date



- Shows the one-off price paid in $/MHz/pop using exchange rate at time of auction
- Includes all assignment methods where a one-off fee was charged
- Licences will not be included if:
    - No one-off fee was charged
    - Information is incomplete e.g. issue date it not known
    - Licences bought in combinatorial auctions are omitted unless the price for the individual band is indisputable

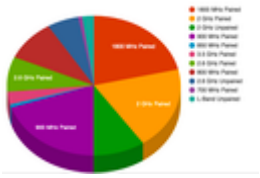
Bar chart: average MHz/pop for all mobile auctions



- Only includes auction prices as these are the more reliable figures
- Shows average prices for all bands in the the PSD
- Calculates the average price paid for a band in each auction then averages all these prices
- Licences will be omitted for the reasons given above

Pie chart: which bands does a particular operator use?

- This is based on a count of the number of licences
- e.g. Vodafone holds 29 1800 MHz licences around the world, which is 21.3% of the total number of licences held by the company

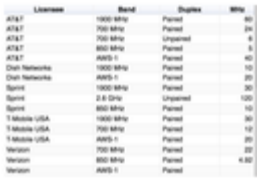


Map: an operator's global licences

- The darkness of the shading shows the amount of spectrum in MHz held by an operator in a country
- N.B. A 5 MHz paired licences is counted as 10 MHz

Table: The national mobile licence holders

- This appears in the countries section
- It shows the licences owned and the amount of spectrum held by the major mobile players



- In some countries with regional licences (e.g. the US) there can be scores of mobile operators, some of whom offer only very localised services
- This chart removes local operators by only counting those licences which cover 40% or more of the country
- In some cases with many regional licences (e.g.India) 30% has been used in order to give a better picture which operators are nationally active
- Licences above 3 GHz are not included in this table as these are not suited to offering national services
- The MHz column shows the total amount of spectrum held in a particular band: e.g. if the operator has several 1900 MHz licences it shows the total spectrum for all of them

Please note:

- A company may hold a national licence but may not be offering services
- Some of the licences shown may not give national coverage